Centre de recherche interdisciplinaire en réadaptation du Montréal métropolitain

McGill
School of Physical and Occupational Therapy

Summer project presentation

Closed loop neurofeedback prototype for adaptive brain stimulation

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Supervisor:
Professor Marie-Hélène Boudrias

System overview

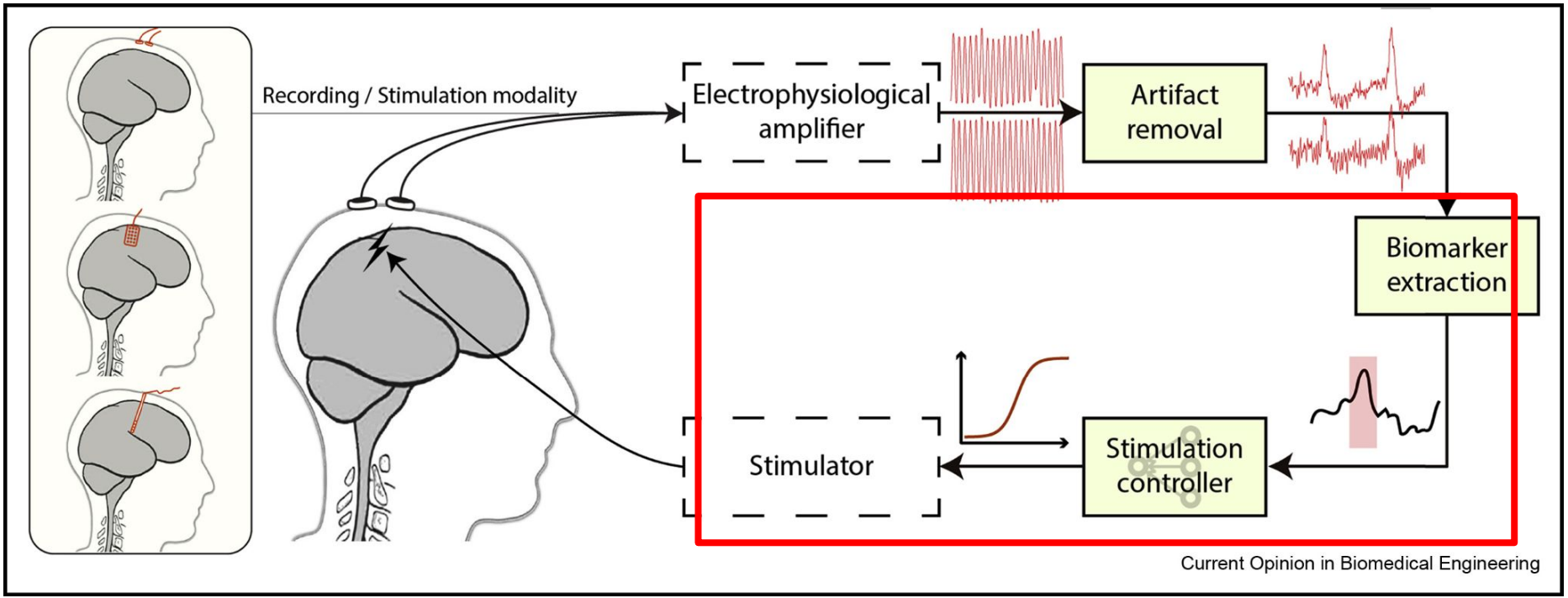
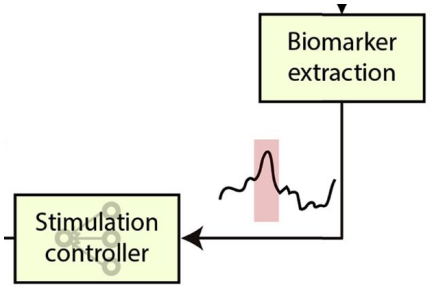


Image source: Iturrate, I., Pereira, M., & Millán, J. R. (2018). Closed-loop electrical neurostimulation: Challenges and opportunities. *Current Opinion in Biomedical Engineering, 8,* 28–37

Summer project overview

Objective: Extract MRBD and trigger stimulation if MRBD below threshold



Current Opinion in Biomedical Engineering

Tasks

1. Feasibility study
2. Online feature extraction
3. ~~Trigger stimulation~~

Image source: Iturrate, I., Pereira, M., & Millán, J. R. (2018). Closed-loop electrical neurostimulation: Challenges and opportunities. *Current Opinion in Biomedical Engineering, 8,* 28–37

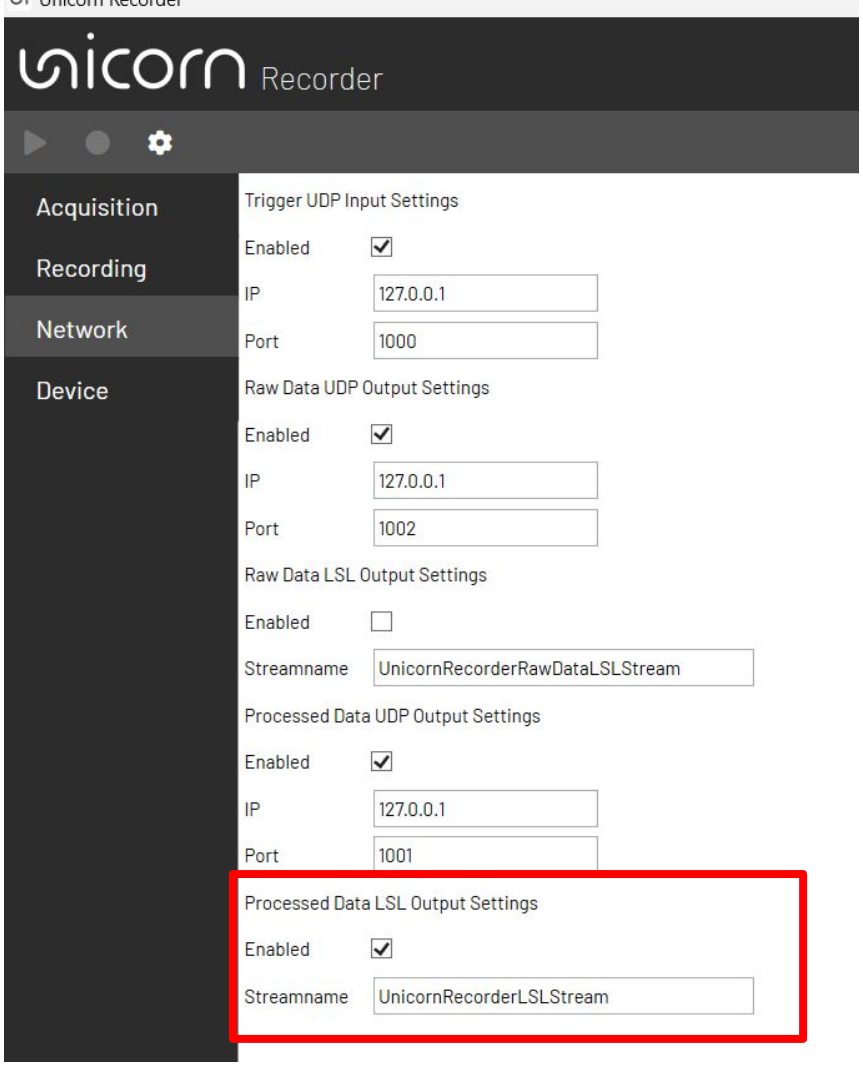
Feasibility Study

Literature Review

- Brain stimulation and why use it in stroke recovery
- Task of interest & detectable features
- Neurofeedback and applications

Requirements

- Real time data access
- Low latency transmission
- Easy integration and system translation


Unicorn Recorder
Acquisition
Recording
Network
Device
Trigger UDP Input Settings
Enabled
IP
127.0.0.1
Port
1000
Raw Data UDP Output Settings
Enabled
IP
127.0.0.1
Port
1002
Raw Data LSL Output Settings
Enabled
Streamname
UnicornRecorderRawDataLSLStream
Processed Data UDP Output Settings
Enabled
IP
127.0.0.1
Port
1001
Processed Data LSL Output Settings
Enabled
Streamname
UnicornRecorderLSLStream

Feasibility study

Find appropriate data access protocol:

Option	Comments
BCPy2000	Outdated, complicated
NeurofeedbackLab	Matlab based, EEGLAB plugins
BrainVision RecView	Live processing, no control over data
LabStreamingLayer (LSL)	Modern, cross-compatible, Python API, low latency

✅Chosen protocol: LabStreamingLayer

Feasibility study: Tools used

Hardware:

- Personal computer
- Unicorn Hybrid Black

Software:

- Unicorn Suite Hybrid Black
- Python
- LabStreamingLayer

✅ Pros

- Wireless
- Dry electrodes
- Easy to use

❌ Cons

- Noisier
- Lower sampling rate

Image source: https://www.gtec.at/wp-content/uploads/2023/09/unicorn-hybrid-black-bundle.jpg

Feature extraction: Record and log data

📌 **Goal**

Detect alpha power shifts in real time → Compare eyes open and eyes closed recording

📶 **LSL protocol**

- Data streamed from UnicornRecorderLSLStream (Processed data)
- Python script to access and log data into csv file

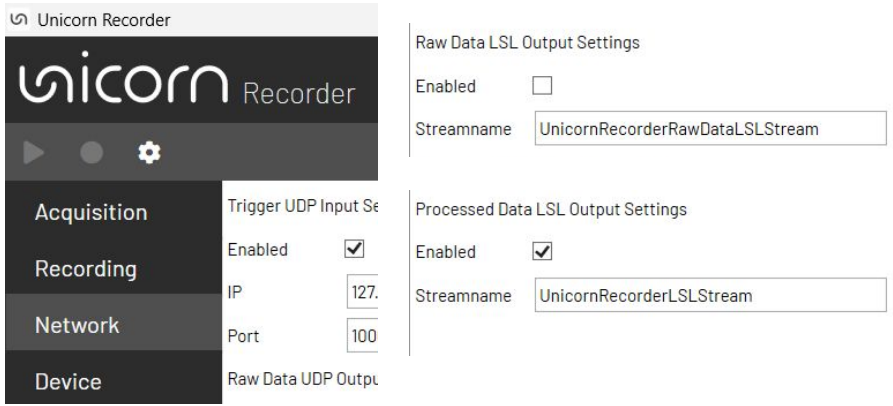


Image source: Unicorn Suite Hybrid Black Screenshot

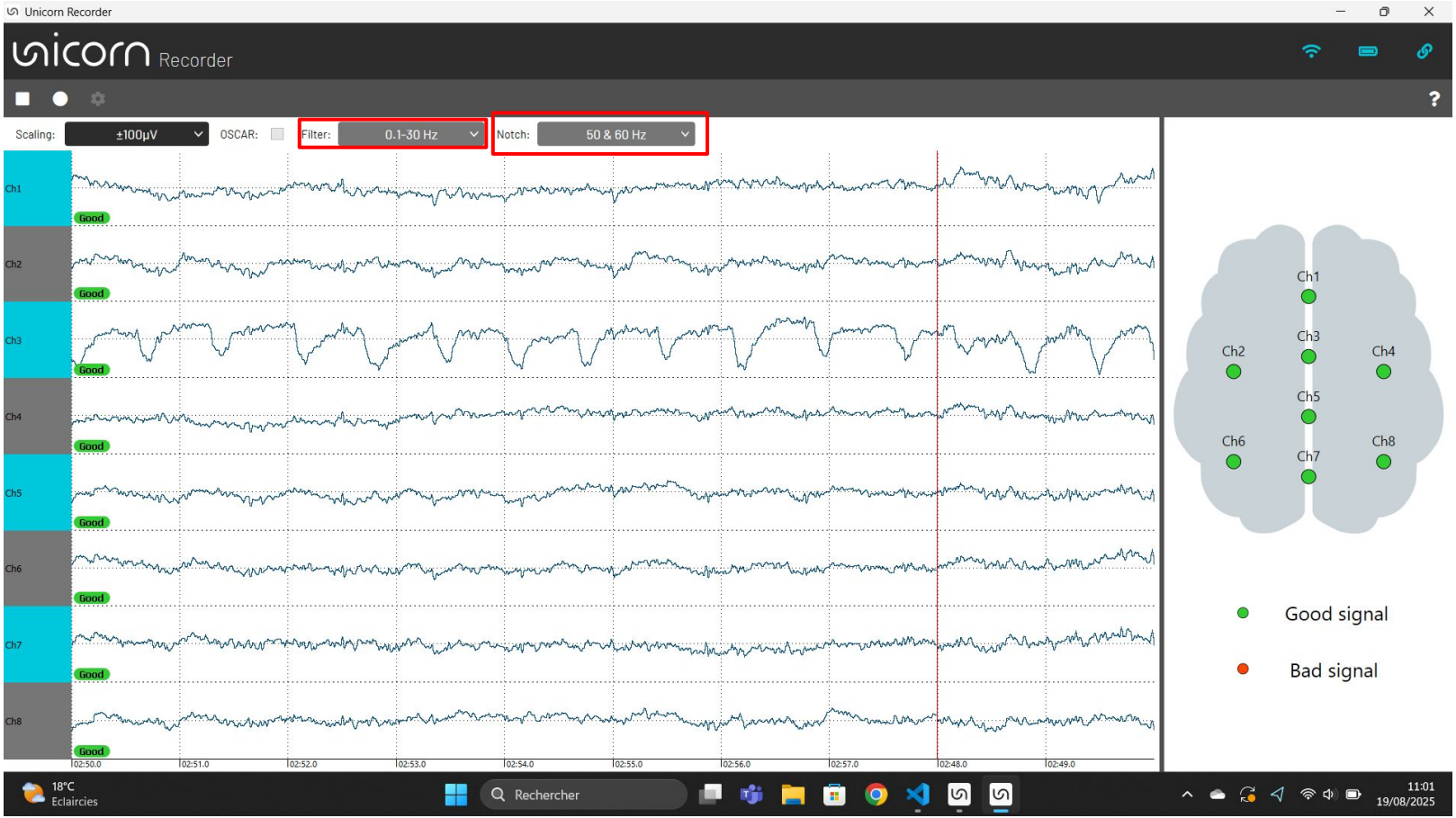
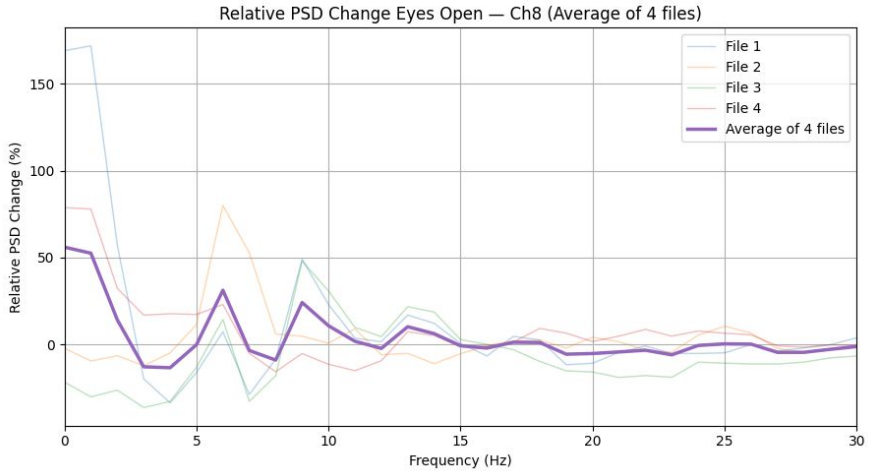
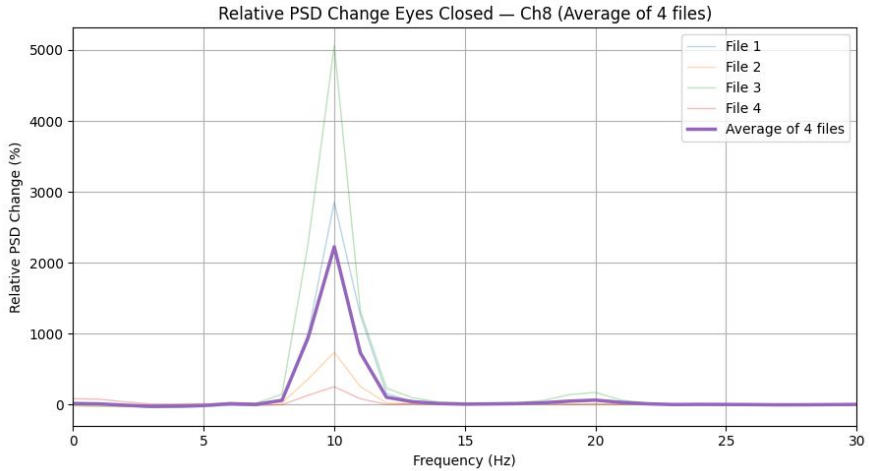


Image source: Unicorn Suite Hybrid Black – Unicorn Recorder Screenshot

Feature extraction: Offline analysis alpha power

Alpha power change between tasks (eyes open/closed) relative to baseline





❌ **Problems**

- Data noisier than expected
- Big variability across trials
- Small baseline values ⇒ big changes

✅ **Detection**

- Clear alpha band increase

Feature extraction: Online extraction

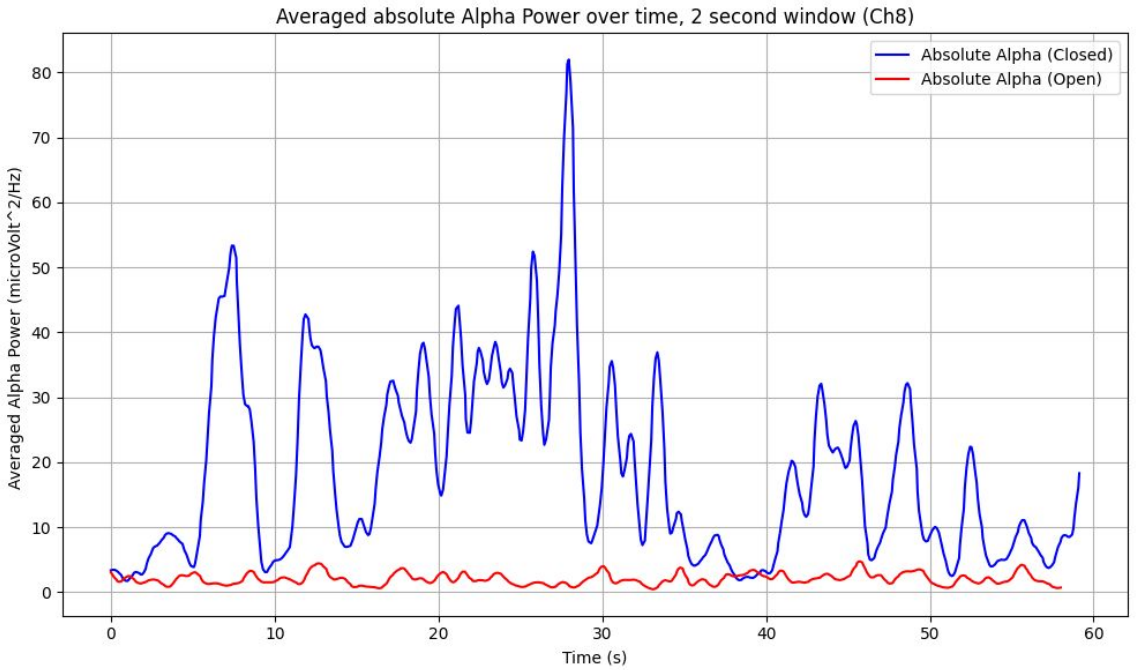
3) Alpha power extraction online logic:

Pseudo code

```
LOOP while streaming is active:
        Pull_sample_from_stream()
        if enough data to compute on a new window:
                if bad_window:
                        BREAK
                Compute_Welch_PSD()
                Compute alpha_power()
                Log data to csv
END LOOP
```

Parameters	Value
Sample rate	250Hz
Window size	2s
Buffer size	Window x sample rate
Step size	10% buffer (90% overlap)

Feature extraction: Online analysis alpha power



❌ **Limitations**

- Very noisy
- Large standard deviation

✅ **Results**

- Successful real-time detection of state changes (20ms)
- Validated pipeline for recording, plotting, and feature extraction

Feature extraction: Offline analysis MRBD

📌 **Goal**

Detect movement-related beta desynchronization (MRBD)

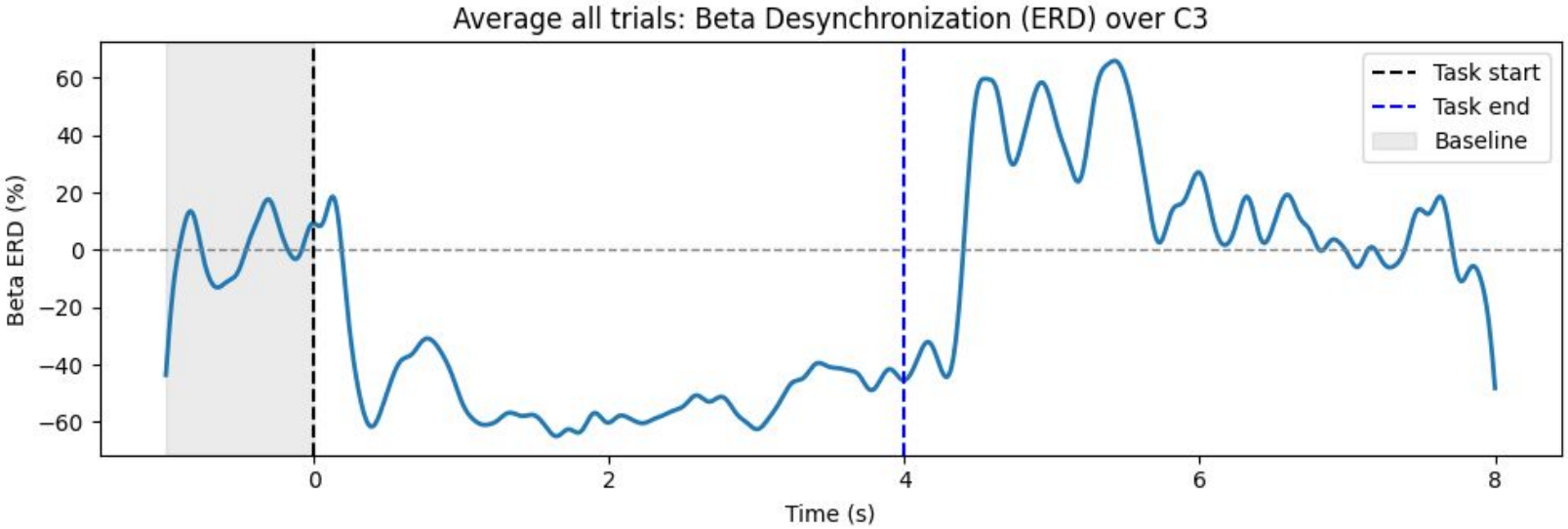
📋 **Method**

- Extend alpha power pipeline to beta band
- 4 second gripping task — 6s rest ⇒ 50 trials
- Morlet wavelet time frequency analysis over C3

Feature extraction: Offline analysis MRBD

✅ MRBD Validation on provided data

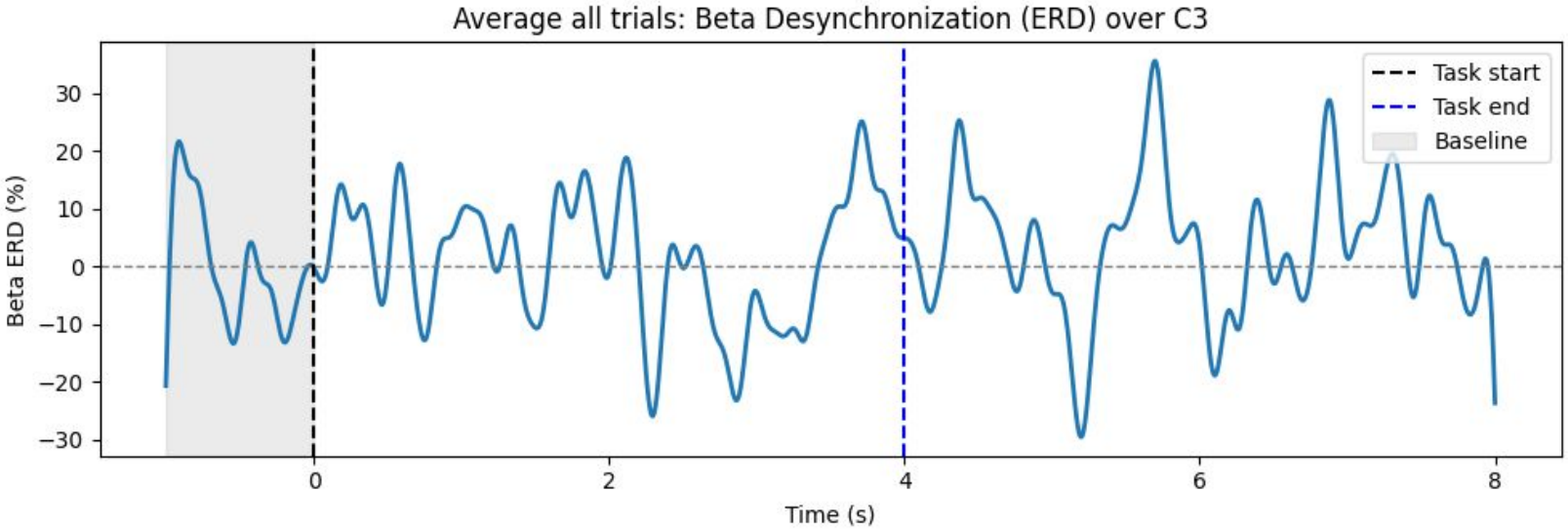
- Clear 50% desynchronization.
- Post movement rebound



Feature extraction: Offline analysis MRBD

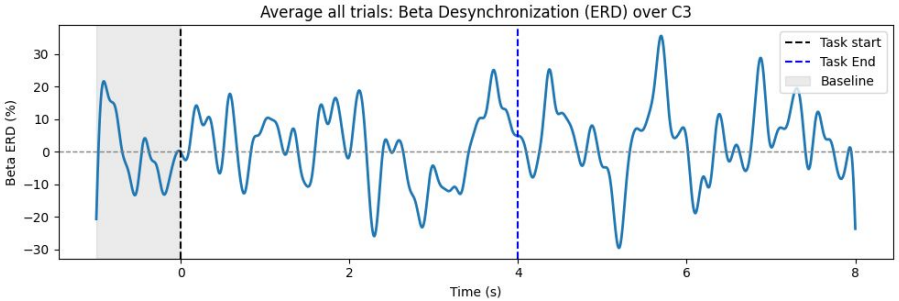
❌ MRBD extraction my own data

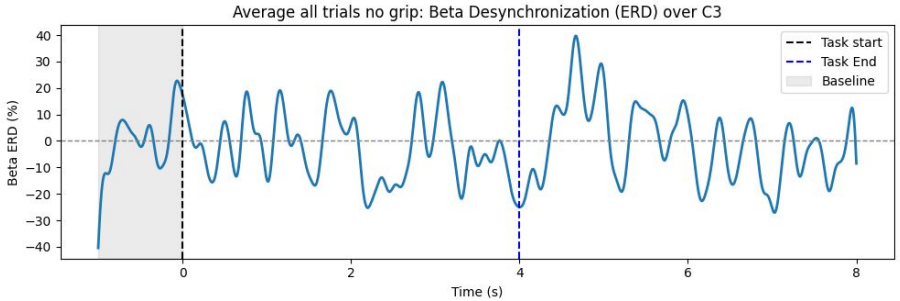
- No clear desynchronization.
- Possible noise/artifact issues



Feature extraction: Offline analysis MRBD

Movement vs No Movement comparison





💬 **Interpretation**

- Task related signal is inexistent
- Beta power baseline is too small and data is too **noisy** which creates very large ERDs

Recap & Next steps

✅ Success

- Real-time feature extraction feasible (alpha)
- Mean alpha change computed live per task

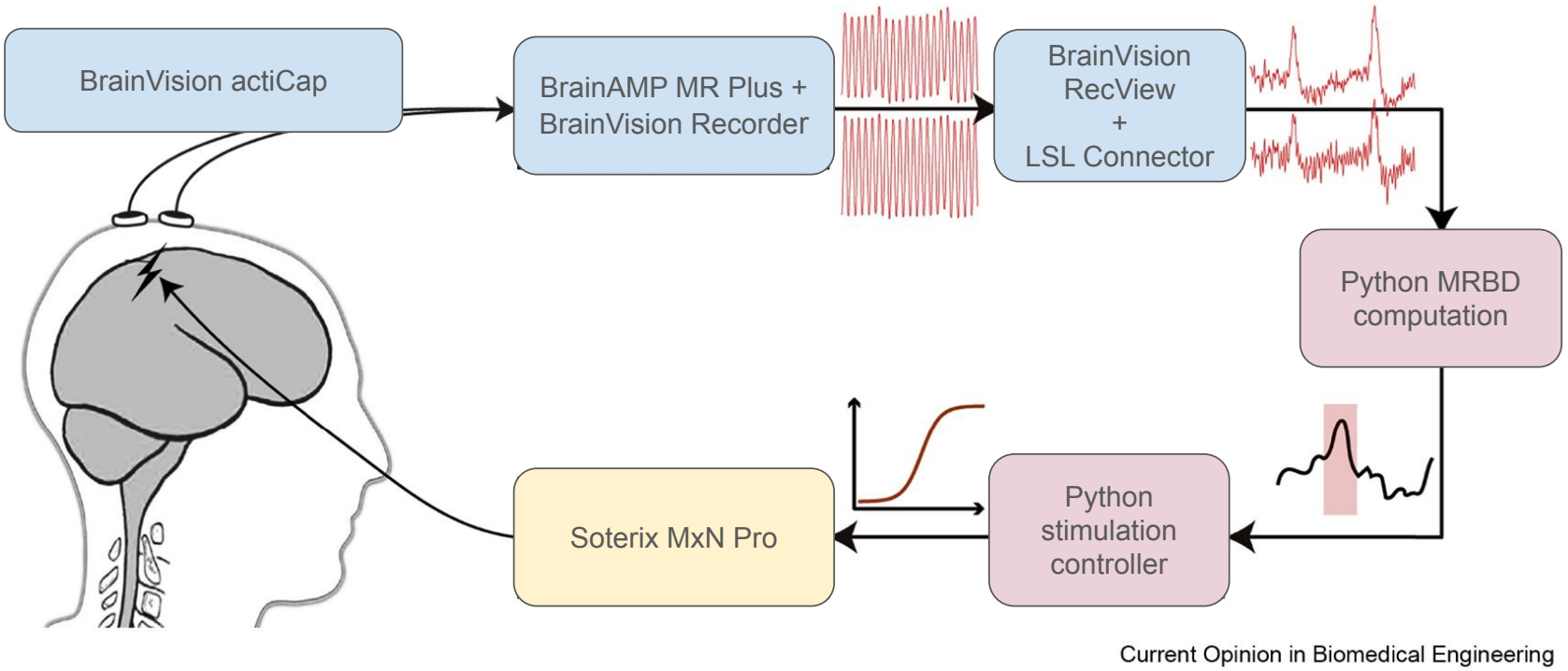
⚠️ Limitations

- MRBD detection harder than expected
- Higher-quality recordings required
- More robust analysis & protocol

🚀 Next steps

- Use BrainVision Cap for better data quality
- Optimize preprocessing (filtering, resampling)
- Improve experimental protocol

Optimal EEG setup for closed loop system



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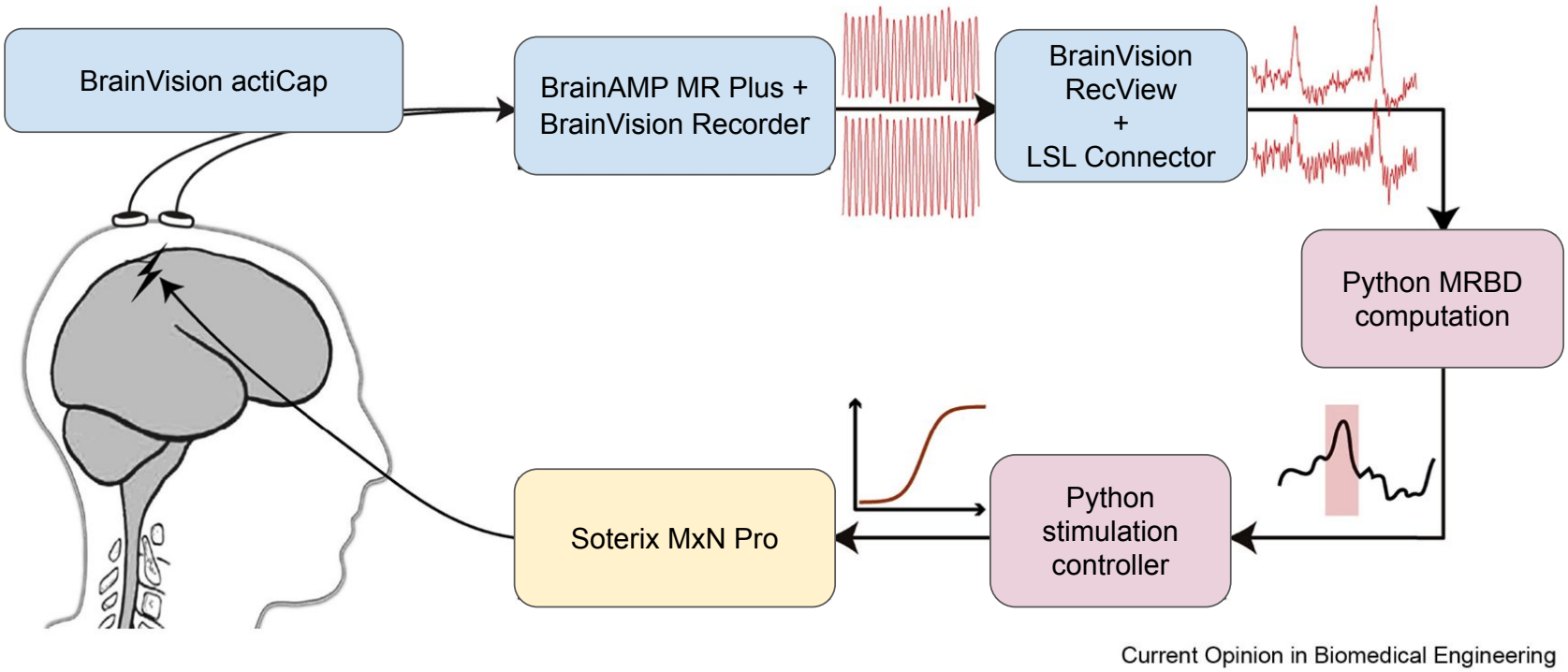
Optimal EEG setup for closed loop system



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Optimal EEG setup for closed loop system

🛒 To Buy

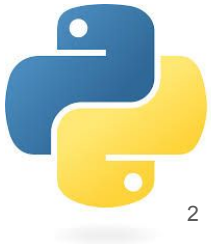
- **Soterix MxN Pro** – fully software-controlled stimulation system

Current limitation: 4×1 HD-tDCS and 1×1 tES cannot be modulated via software.

1

💻 To Develop

- Live MRBD computation
- Stimulation trigger



2

Images sources: 1) https://soterixmedical.com/static/images/mxn33/mxn-pro-main-3.png
2) https://upload.wikimedia.org/wikipedia/commons/c/c3/Python-logo-notext.svg

What I learned

🔧 Technical skills

- Real time processing pipeline using Python and LSL
- Online and offline feature extraction
- Hands on experience with EEG hardware

🔬 Research experience

- Learned importance of iterative testing and refining methods
- Problem solving on real use cases
- Patience and resilience
- Unexpected results are as important as expected ones

Thank you for your attention!

References

Bibliography:

I. Iturrate, M. Pereira, and J. del R. Millán, “Closed-loop electrical neurostimulation: Challenges and opportunities,” Current Opinion in Biomedical Engineering, vol. 8, pp. 28–37, 2018. doi: 10.1016/j.cobme.2018.09.007

Morales Fajardo K, Yan X, Lungoci G, Casado Sánchez M, Mitsis GD, Boudrias MH. The Modulatory Effects of Transcranial Alternating Current Stimulation on Brain Oscillatory Patterns in the Beta Band in Healthy Older Adults. Brain Sci. 2024 Dec 20;14(12):1284. doi: 10.3390/brainsci14121284

Images:

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2) https://soterixmedical.com/static/images/mxn33/mxn-pro-main-3.png
3) https://upload.wikimedia.org/wikipedia/commons/c/c3/Python-logo-notext.svg